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Reply on RC2

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Author comment on "Echo state network model for analyzing solar-wind effects on the AU and AL indices" by Shin'ya Nakano and Ryuho Kataoka, Ann. Geophys. Discuss., https://doi.org/10.5194/angeo-2021-54-AC2, 2021

We are grateful to the referee for the helpful comments. The followings are our responses to the comments.

> Introduction: To increase the interest of his paper for general audience the authors should give a bit broader explanation what are auroral indices (what current systems they try to measure) and how previous studies have found that solar wind properties control them (parameters that are the most important and why). Discussion has partly this information, but could be already here.

We will add more explanation on the auroral indices. We appreciate the referee for the constructive suggestion.

> Introduction: Authors could also discuss in the Introduction why they expect to detect non-linearities.

Most of widely-used machine learning models are designed for representing nonlinearities. An echo state network (ESN) can also be used for predictions of nonlinear systems because it contains nonlinear functions as described in Eq. (1). Indeed, Chattopadhyay et al. (2020), which is cited in the introduction section, shows an example which represents nonlinear dynamics by an ESN. In the revised version, we will mention that an ESN is widely used for applying to various nonlinear problems.

> Pages 72: Is this now meant to take into account the timelag between solar wind parameters and AL/AU response? What is the typical timelag giving the best result? Also the optimal timelag could vary depending on the solar wind parameter in question, could that have an effect to the results or their interpretation.

Here we intend to say that the ESN refers to a time sequence of the input data for making a prediction. Each of the state variables of the ESN is obtained by a nonlinear conversion of the previous state variables according to Eq. (1). The ESN thus keeps the history of the

input data in memory. A prediction by the ESN is based on the history of the data. In order to predict something using the ESN, a sufficient time sequence of the data must be fed as an input in advance.

The timelag between the input and output would be learned when training the ESN model. However, the timelag is not given by a specific parameter in the ESN. It is difficult to quantify the timelag using the trained ESN model.

> Figure 1 discussion: It seems that the model consistently underestimates the observed values both for AU and AL. What is the expected reason to this.

There is no expexted reason to underestimate the observed values. We think that the difference between the prediction and observation would be zero on average. However, since the ESN model cannot represent short-term variations in detail, the ESN output tends to be much smoother than the observation. The amplitudes of the short-term variations thus tend to be reduced in the model output. Maybe this is the reason why it looks as if the model underestimates the observation.

> Figure 1: Top panel label is AE, should rather be AL & AU?

We agree with the referee. We will revise the label.

> Page 138: Does synthetic mean here that the AL and AU show are produced using solar wind observed gathered 21 October to 25 October in 1999? Would it be better call it modelled than synthetic?

In Figure 7, the red line shows the model output obtained with the observed solar wind data. On the other hand, the green and blue lines were obtained with artificial inputs where one of the solar-wind parameters was fixed at a constant. The main purpose of this figure is to show the results with synthetic inputs, and we refer to them as the synthetic AU and AL indices.

> Figure 7: colors are not well visible here in the top panel. E.g., I cannot see any green line.

We will change the color of the green lines as below. We appreciate for the comment.